

500-xxx-xxxx MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

MO&DSD **Process Guide Proposed By** Renaissance

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National Aeronautics and Space Administration

Goddard Space Flight Center ____ Greenbelt, Maryland

Preface

This MO&DSD Process Guide Proposed By Renaissance is chartered by the Renaissance activity in the MO&DSD systems engineering office, Code 504. It is at the conceptual level for how MO&DSD could do business. It presents an integrated set of recommendations to solve specific problems with the current process for the mission ground system market. If accepted as the MO&DSD process, it is intended to be supplemented by handbooks which contain the detailed processes. It does not address all potential markets for which the MO&DSD can or could participate.

The MO&DSD Process Guide Proposed By Renaissance was prepared by the Renaissance Process Engineering Group. Please address comments to the chair person listed below.

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Abstract

The MO&DSD mission process evolved to produce high quality ground system support for large scale missions with a minimum of risk. This evolution also occurred over the period when large, mainframe-based computing facilities were the most cost effective. In order to reduce risk, great care and expense were directed to a detailed understanding of requirements and design. Each institutional facility strove to prevent misunderstanding by detailed interface control documents with other facilities and organizations, and each with the customer organization. The resultant process, although highly reliable, was relatively costly, slow, and forced the customer to deal with numerous MO&DSD organizations.

Upcoming missions are expected to be low cost and short duration. Customers expect a process to obtain ground data system (GDS) services traded with the spacecraft and science objectives. GDS options outside of the MO&DSD are made possible by technological advances in networked workstations, communications, and a wide array of commercial and government off-the-shelf (OTS) products. System and software development techniques have also evolved to allow higher productivity with known levels of risk. The organization formed by functional "stove pipes" does not allow MO&DSD to easily adapt to new ways of producing.

This *Process Guide* is intended to outline the concepts which, if adopted, would enable MO&DSD to better meet customer needs. This challenge can be met through a customer-focused, intensive teaming approach using primarily OTS products in a rapid prototyping method during the full mission lifecycle. The intensive teaming approach provided through the virtual corporation concept breaks down barriers to communication and allows teams to adapt to new processes and technologies so that MO&DSD can respond more quickly to customer needs at lower cost. Cost saving is achieved through forming customer-focused teams composed of the people with the needed expertise interacting in an informal setting which eliminates much of the need for traditional formal interface documents (e.g., DMR, ICDs). This team is empowered to determine the most appropriate use of process and technology. It is further broadened to efficiently address missionlevel goals by partnering with the non-MO&DSD teams with the expertise on the spacecraft, launch vehicle, and science objectives. Concept to launch lifecycle times and costs are minimized by taking advantage of the rich selection of OTS products integrated and configured using a rapid prototyping method as both a basis for establishing ground system needs and validating it for operational use. The target market is thereby expanded from the mission ground operational system to also optionally include the spacecraft integration and test system, and the science data reduction system.

The GDS includes the space to ground link, data distribution, flight dynamics, command and control, health and safety monitoring, mission planning, and science data processing. The approach addresses full mission costs to trade off placement of functions in a distributed ground system versus onboard the spacecraft, and development of automation versus operations.

Keywords: [COTS, data systems, GDS, ground data systems, Integration, mission support, Process, Reengineering.]

Section 1. Purpose

1.1 Overview

New flight project customers reflecting low cost, higher risk class missions are dissatisfied with the high cost and inflexibility of mission operations available with our legacy systems. To demonstrate that we are cost effective and to establish a reputation for being responsive to customer desires, we have to build an organization capable of learning to do business in new and innovative ways. Our customers now have options other than MO&DSD, so we need to reengineer our business processes, keeping in line with the NASA vision and goals. The MO&DSD continues to provide excellent technical solutions. This *Process Guide* suggests an approach to maintain technical excellence and solve this customer service problem.

One of the most severe problems that MO&DSD faces is that market opportunity time frames are decreasing, therefore we need to "shrink wrap" our system components, assemblies, and operational scenarios. We need to virtualize our capabilities, so we can tailor our products and expertise for each client. The ultimate keys to success are meeting mission goals with rapid response and low cost.

The greatest opportunity to reengineer the process is by taking advantage of new solutions made possible by changes in technology. MO&DSD must also replace it's minimal risk approach with a risk assessment, risk mitigation approach where acceptable levels of risk are targeted in order to become cost effective and responsive to our customers. Secondarily, there is a need to reinforce the NASA goal to advance and even extend technologies and transfer these to the private sector.

The Renaissance activity was chartered to address the possibilities of new architectures and processes based on recent and emerging technologies. These goals were established:

- Be responsive to each individual (MO&DSD) customer.
- Create reusable building blocks (in-house OTS products).
- Identify and demonstrate integration of reusable OTS products.
- Simplify the customer interface.
- Perform development (system integration) and, optionally, to perform operations that are cost effective from the macro economic perspective.

In order to achieve these goals, the following recommendations are made:

- Projectized MO&DSD support of missions.
- A shift of emphasis from delivering mission products and services to delivering an integrated ground data system (GDS) consisting of reusable standard components and customer specific features.

- Minimized and consolidated interfaces into and within MO&DSD.
- Utilization and maintenance of our centers of expertise (COEs).
- Ability to perform operations fully or partially within MO&DSD, or at any remote facility.

In this *Process Guide*, the GDS is understood to include all traditional ground system functions as listed here, and to promote the automation and transfer of these functions to onboard the spacecraft.

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•	Space To Ground Link	•	Flight Dynamics	•	Command And Control
•	Data Distribution	•	Health And Safety Monitoring	•	Science Data Reduction

Mission Planning

The MO&DSD as it has been structured in the recent past, was optimized to build and operate ground support for big missions with moderate reuse. The business has been evolving towards more small missions with high reuse and the concept of higher acceptable levels of risk. This has caused cumbersome coordination processes which resulted in high overhead on the shrinking per mission budgets.

To address this shift in customer needs, the integrated product team approach is recommended to remove marginal value-added checks and balances for coordination and quality assurance. Quality will rely on teams with the necessary skill mix empowered to be self-directed to cost effectively solve mission problems. Engineering communications will be direct and informal.

The mission teams will optimize performance if teamed with the spacecraft integration and test (I&T) and science operations mission members. This alliance will provide for more cost effective ground components, and for effective exploration of trade-offs between the various mission components including the spacecraft. It will also provide the framework for consideration of moving traditional ground components to the spacecraft.

Systems development will be based on incremental prototyping with a heavy emphasis on configuring and integrating off-the-shelf (OTS) system components. This will result in the ability to gain meaningful customer feedback to tangible demonstrations of the incremental prototypes which finally result in an operational mission support system.

1.2 Perspectives

From the MO&DSD perspective, both internal and external factors must be considered to understand the overall MO&DSD market and development environment. To determine how MO&DSD will deal with change, issues such as the following must be resolved:

- What forces shape the market for MO&DSD products and services? These forces include the science objectives, public funding through the federal government, changing national priorities, and competition made possible by advances in technology.
- How do we respond, and how should we respond, to these forces? The MO&DSD will continue research in GDS and related technologies, and continue to advance the state of the art in mission design and system integration, and finally to stimulate the commercial sector through use of commercial products and services whenever they are cost effective.
- What are the roles and relationships among customers and suppliers, both internal and external to MO&DSD? The MO&DSD must clearly identify their customers and suppliers: government, academic, and commercial. The potential customer base can range beyond the traditional boundaries, especially where similar government functions can be consolidated, and as long as commercial opportunities are not jeopardized.
- How does MO&DSD meet customer needs in a changing environment? The MO&DSD must be willing to reengineer its business processes, so they are as dynamic and innovative as is required for each customer. The new set of processes are then subject to iterative refinement, introduction of new options, and ultimately to be reengineered again when needed. This level of flexibility ensures the ability to meet customer needs.
- How can MO&DSD provide early and reliable cost and schedule estimates? The knowledge base of GDS architectures, building blocks, and operational scenarios is captured in the MO&DSD repository as it is defined in this process guide. This knowledge is continually updated through feedback from customers and market surveys. These repository items each contain the corresponding costs associated with system production, maintenance, and operation, and the interface to the repository facilitates quickly configuring a GDS for a specific set of customer needs and tallying the corresponding costs.
- How can development processes be defined to guarantee on-time delivery of GDSs that meet customer system reliability, performance, and cost requirements within acceptable risk margins? The repository will contain an increasing selection of commercial and government OTS (COTS and GOTS) products with known integration methods and performance characteristics thus enabling reliable estimates of integrated system performance. These can be assembled in evolving, rapid prototypes which result in increasingly functional, operational versions of the final product.

The above process improvements will facilitate "faster, better, cheaper" product and service delivery to our customers, and will thus ensure the continued need for the MO&DSD. The approach to address these changes is outlined in the remaining sections of this *Process Guide*. Section 2 outlines the overall product marketing approach and customer focus including the core MO&DSD functions and teaming strategies. Section 3 describes the mission engineering processes to focus on each mission customer. Section 4 describes the system engineering processes which provide the reusable assets for the mission engineering. Section 5 addresses configuration management. Section 6 outlines the risk management process and approach. Section 7 identifies subsequent recommended studies.

Section 2. Customers and Products

2.1 Market Characteristics

The characteristics of the MO&DSD market include a wide range of missions that require similar functions with a potential for highly common solutions. This is supported by trends toward:

- Small, short duration missions
- Customers that expect to measure the value they receive for money spent
- Significantly reduced NASA budgets

The industries supporting space science have evolved and matured. They now offer products that implement functions previously (thought to be) unique to NASA strategic enterprises. We now have available many COTS products and numerous industry standards which can aid in meeting the challenge of change.

2.2 Customer and Product Focus

Figure 2-1 illustrates the MO&DSD customer interface and internal supporting functions. The product is a GDS tailored and integrated for a specific mission and deliverable to a customer or MO&DSD site, optional operations in support of the mission, and various areas of consulting expertise. This model shows the focus on customer needs.

The supporting functions are:

- **System Engineering** defines the system architecture, design, and operations scenarios. The integration of operations engineering with system design, provides the ability to address the effective optimization of manual operations with respect to the underlying automation systems.
- **Mission Operations** is available to optionally operate those systems for which the MO&DSD performs operations. This function is intended to include all operations activities. These teams will optionally perform science data preparation and analysis (i.e., can be collocated with or perform science data reduction) under mission scientist direction.
- Mission Support (centers of expertise) provides support of all systems and services
 provided by MO&DSD. These include consulting for pre-mission, operations problems,
 product support (e.g., help desk or flight dynamics analysis), maintenance of the
 systems for which maintenance is requested, and training of MO&DSD and customer
 staff in using or maintaining products.

• **Mission Teams** serve as the single point of contact and interface with the mission customer and are supported by the other MO&DSD functions. These mission teams also collect the lessons learned and feed them back to the supporting functions.

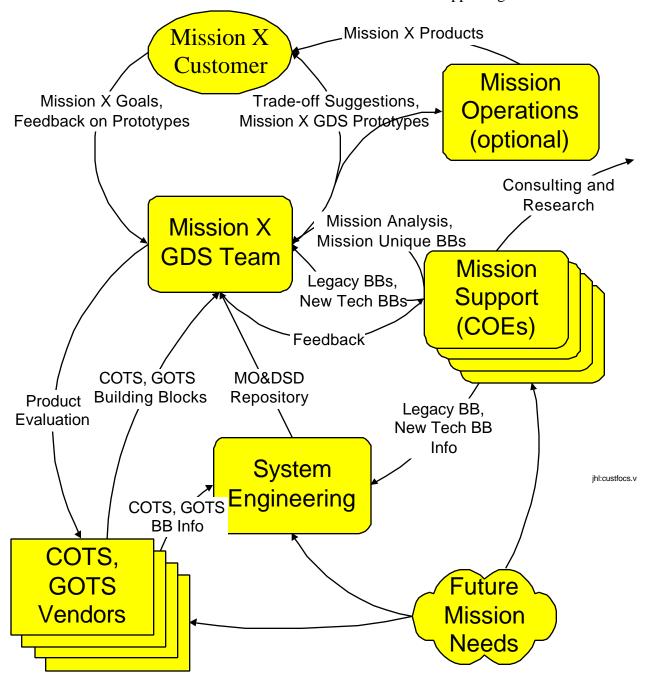


Figure 2-1. Mission Customer Focus.

A traditionally time consuming and expensive activity was the process to derive and document the GDS requirements. An elaborate process was required when each GDS was essentially a new unique product with low to medium levels of reuse. In the current era of configuring and

integrating OTS products, this process can become much more efficient. The Mission Requirements Request (MRR) continues to be a suitable means of recording mission ground support needs when capturing mission requirements during a traditional new start mission process. It needs to be written in the customers language and kept brief. In the current era of announcements of opportunity, the proposal contains a sufficient statement of the mission needs and may already be supplemented with an initial GDS prototype.

The Detailed Mission Requirements (DMR) have been used to document the detailed mission needs and show the allocation of requirements to the various MO&DSD internal organizations for development. It also serves as the vehicle for agreement between the MO&DSD and the mission customer. It is accompanied by a Mission Operations Concept Document (MOCD) for documenting the MO&DSD understanding of the mission needs from an operations perspective.

In the emerging era, the DMR, which is greatly unchanged across missions, can be replaced with the equivalent material in the MO&DSD repository. This contains on-line specifications and operations scenarios of the standard OTS reusable building blocks and architectures, and the knowledge base of lessons learned from previous missions. Detailed analysis and design will only be required for mission unique functions to be developed and only to the extent that is needed for new reusable assets to be added to the repository.

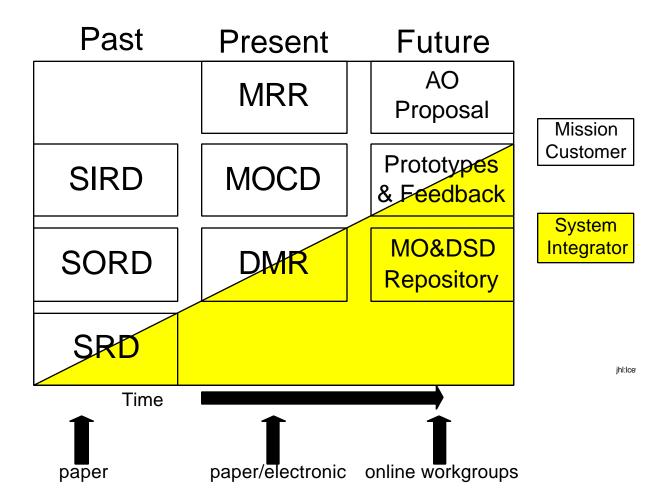


Figure 2-2. Evolution of customer/developer GDS negotiations.

The object of agreement with the mission customer has been evolving from the DMR to the MOCD which describes how the GDS performs its functions thus raising the level of abstraction from a system specification to the operators language. This can be further abstracted by using the series of prototype demonstrations to gain feedback from the mission customer and agreement on the final product. The prototypes facilitate an efficient requirements management process because negotiations occur based on actual demonstrations, and the prototypes are iterated to become the delivered GDS.

Figure 2-2 illustrates the trend to documenting mission needs more abstractly. Horizontally, the information is being recorded with increasing efficiency. Additionally, the point of negotiation and agreement with the mission customer has moved up vertically to be more meaningful to the mission customer.

2.3 Teamwork through the Virtual Corporation Concept

In order to provide products and services which are tailored for each mission customer, the MO&DSD would be a virtual organization (i.e., as in the virtual corporation). The basic building

blocks for this virtual organization are teams which are tailored for each customer, and are formed by selecting the appropriate skill mix from the centers of expertise. The mission teams are examples of teams configured for each customer based on specific customer needs. This concept is illustrated in Figure 2-3. Mission GDS teams are described in more detail in the mission engineering process section. There are also other types of teams formed to solve specific problems. Note that the ability for the MO&DSD to change rapidly lies in the ability to rapidly reconfigure teams to match customer needs and, in addition, to rapidly draw from corporate memory which is in the electronic MO&DSD repository.

The traditional practice of participating in integrated mission teams with the customer organizations has proven to be beneficial in that MO&DSD can provide feedback and suggestions to the customer assumptions in a timely manner. This approach can be further encouraged for the product markets of the mission operations center (MOC), science operations center (SOC), and the spacecraft I&T. These three support systems overlap in system component functionality, but satisfy different mission needs and require different types of mission expertise. A mission-focused teamwork approach including the mission customer, mission scientists, spacecraft manufacturer, launch vehicle team, and the MO&DSD mission GDS team without organization barriers can efficiently produce these support systems.

This teamwork option, to some extent, is available today and is already being practiced to varying levels on current missions. The integrated mission team responsible for a total mission can better trade-off allocation of functions to ground and onboard the spacecraft, and can trade off automation and product cost options against full lifecycle operational and maintenance costs. The ability to effectively trade-off development, operational and maintenance costs is further supported by fully funded, cost capped missions which are becoming the typical profile. It is currently difficult to perform space-ground trade-offs for full life-cycle costs because of the distinct separation of ground and space segment development each focusing on their single domain and seldom able to truly focus on long term operational and maintenance cost trade-offs during mission development.

The mission-focused team can obtain additional efficiencies through the use of on-line workgroup systems and the computer repositories which act as a corporate memory. These methods and tools for communication can replace much of the costly interface documentation currently required. The time scale for communication is greatly reduced and the interfaces can evolve more easily with the series of system prototypes.

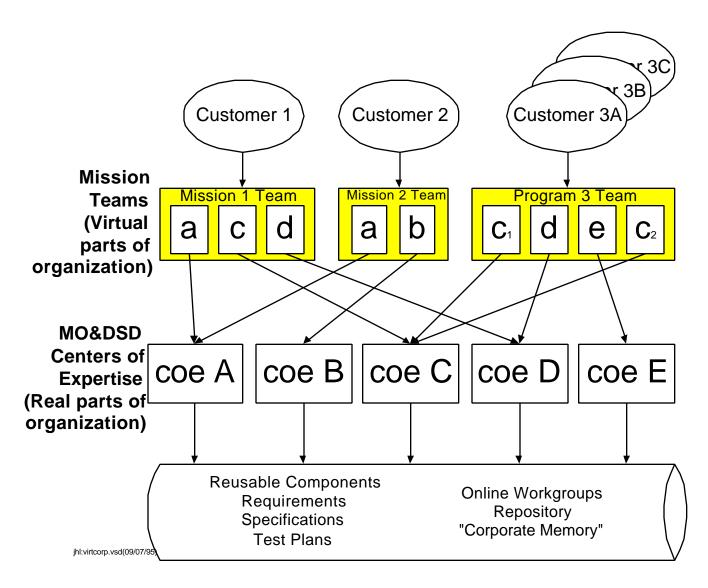


Figure 2-3. MO&DSD as a virtual corporation.

Section 3. Mission Engineering Process

3.1 GDS Development Overview

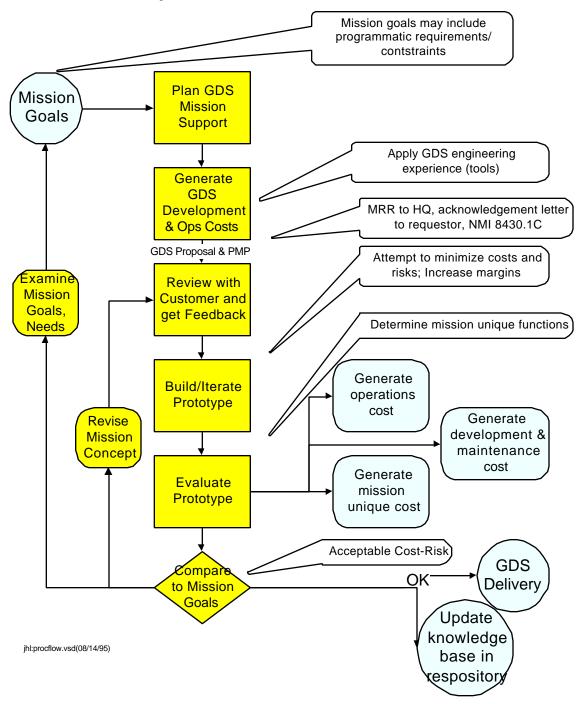


Figure 3-1. The Mission GDS Lifecycle Process

As seen in figure 3-1, at the core of GDS development is an iterative process of producing prototype versions of the GDS followed by evaluation against mission needs. When the mission needs are met, the prototype becomes an operational baseline (including possible use for spacecraft I&T at the appropriate point in the lifecycle). Subsequent iterations may be performed as needed to update the baseline due to changes in mission needs, changes in product support, or other advances in technology. For short duration missions, optional upgrades for product support or advanced technology may not be cost effective and are not required. A sample 14 month GDS development schedule including traditional development reviews is illustrated in figure 3-2.

An outer iteration loop is defined in the GDS development process to revisit the mission goals. This may be needed if external mission parameters change, if the mission goals (including cost and schedule) cannot be met as is, or if other potentially advantageous trade-offs between the ground elements and the spacecraft, launch service, or science objectives should be considered. Based on mission goals, a GDS proposal is produced by determining selection criteria and applying these to the architecture and design templates in the repository. The selected design forms the core of the technical approach and is supplemented with a management plan and cost estimates. These may be documented as a proposal for an announcement of opportunity, or as the technical and management approaches along with the MRR in a traditional process. Depending on the circumstances, the initial selected design may be immediately prototyped for demonstration and cost refinement.

The MO&DSD repository contains knowledge of the relationships between operational scenarios, OTS system components (software elements), and costs related to system production, operation, and maintenance. This knowledge, in conjunction with the integration techniques, provides the capability to not only readily estimate lifecycle system costs, but also to then quickly produce a system prototype which demonstrates the ready capabilities and precisely identifies those mission unique or otherwise missing capabilities. Given a rich selection of architectures and designs based

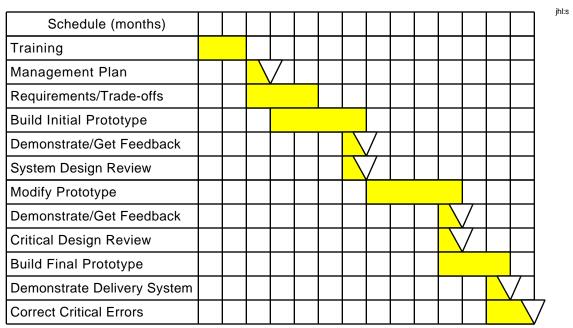


Figure 3-2. Sample Mission GDS Development Schedule.

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on OTS products, much of the prototype production process is concerned with configuring, integrating and verifying products.

3.2 MO&DSD Repository

The mission GDS development process is centered around use of the knowledge stored in and accessible from the MO&DSD repository. This process is focused on the MO&DSD customer who has science objectives and needs a GDS and, possibly, operations. The repository contains all of the knowledge required to cost, assemble, and operate a GDS. The Code 501 PACE effort has produced a prototype ground, operations, and costing tool which could become part of the repository.

The repository contains information about building blocks, but can reference the detailed information, such as specifications, from the building block provider. The providers can be internal to the MO&DSD and based on both legacy system components and newly developed ones. Providers can also be GOTS from outside the MO&DSD, GSFC, or even NASA. Another source of providers is the COTS marketplace which has recently begun to offer quality application software products relevant to the aerospace domain. Finally, non-aerospace domains, such as factory process control systems, contain system components and technologies that are directly usable in the aerospace domain.

3.3 Mission GDS Requirements Gathering

The requirements gathering approach is a negotiations process whereby the mission customer and mission GDS team start with the architecture and design templates in the MO&DSD repository, select the best fit, and then tailor (configure and integrate) that to mission needs. Feedback from the mission customer is sought based on the initial template selection and from demonstration of prototypes. This process also provides identification of what is not readily available as recorded in the repository. The requirements are formulated at a high level and focused to maximize use of OTS products. In parallel with this activity, cost and strategic trade-off study and negotiations are conducted. Costs are minimized to satisfy the user for functionality, but technical approaches are also selected which support the MO&DSD strategic directions.

3.4 Prototype Construction

The repository contains architecture and design templates and the customer can explore how they fit mission needs. Architecture framework is the focus for system integration. Multiple designs are constructed around a common framework using standard models. Mission design is selected based on closest match to mission needs, and modified to get best fit within cost constraints. Multiple integrated systems are possible from each design using standard data interfaces.

This approach provides the key to "black box" usage of system components through standard data interchange, built-in performance options, and built-in technology insertion. Configuration data supports evaluation of the options which leads to a focus on off-the-shelf implementation. This reuse process is illustrated in figure 3-3.

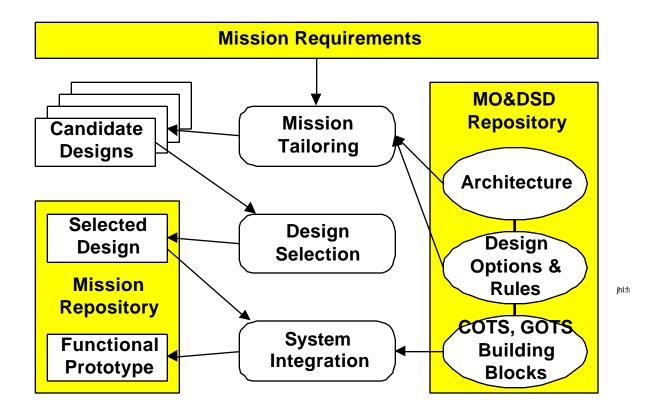


Figure 3-3. Framework-based Reuse Concept.

3.5 Integration of System Components

One of the key process steps is the integration of various OTS products. This is facilitated by adherence to the Renaissance standards which define the software backplane concept. There are several approaches to integration through the software backplane. In one instance, an OTS product already meets the application program interface (API) defined in the software backplane. OTS of this variety already meet the "plug" part of the "plug-and-play" goal, and only require configuration to meet the remainder.

Other products can be interfaced through the standard API set through a wrapper developed to translate protocols and "plug" the OTS product into the backplane. Many OTS products are suitable for linking in a protocol translation wrapper to meet the backplane API specification.

The final approach is to establish gateways where use of the backplane API is not directly feasible, but the use of the OTS product is otherwise cost effective. This approach may be cost effective for integration of the system, but can introduce operational inefficiencies due to non-standard interfaces. Using the standards-compliant file interface system as the gateway between applications is frequently well suited for applications which are not time critical. In some cases, small programs are required to transform the output from one application to the form required for input to the next.

3.6 System Verification

The iterative prototype process described for the mission GDS development includes a frequent integration strategy whereby as pieces of the system are completed, they are integrated and tested. The GDS is intended to be used on a continuing basis by experienced operators (e.g., flight/mission operations team members) and if possible by those intended to operate the mission as it evolves into the operational system. This means that there is no separate formal system, acceptance or readiness testing (except for customer acceptance as determined by the mission customer). Since these operators frequently use the prototypes, they know best how to rapidly test the components and can give the system integrators rapid feedback on problems.

This system verification approach can also expand to include the spacecraft I&T, launch system integration, and science data processing as requested by and negotiated with the mission customer.

Section 4. System Engineering Process

4.1 Domain Analysis

Requirements gathering is concerned with domain analysis within the target markets. Domain analysis is concerned with identifying the requirements of spacecraft support GDS problem domains. Domain analysis looks at future trends, current needs, and existing generic capabilities to identify new generic capabilities. Capabilities which can not be satisfied with existing generic capabilities are sent to domain analysis to determine if new generic capabilities should be created. Domain analysis is an ongoing process that is fed by the announcement of new missions, the discovery of new trends in spacecraft needs, and new developments in technology. It is also an iterative refinement process based on feedback from previous missions.

4.2 Repository Maintenance

The first generation MO&DSD repository is the Renaissance building block catalog. This document is the simplest form of the repository. It contains descriptions of the recommended set of legacy-based building blocks and those planned to be developed or enhanced for current missions. It also contains the architectural description of how these building blocks are integrated into cohesive systems.

As the repository is populated with qualified OTS products, the most suitable integration approaches will be identified along with nominal configurations and any previous customizations. The repository is continually expanded and improved. The improvement of the repository, as shown is figure 4-1, is derived from:

- Feedback from mission customers and MO&DSD integrators/evaluators
- Survey and evaluation of the OTS market offerings including investigation into the nonaerospace domains
- Analysis of the likely needs of upcoming missions
- Analysis of the forecasts of technology changes and the MO&DSD research into technology advancement

Feedback from each mission team (and mission customer) which is relevant to other missions is recorded in the repository knowledge base. This knowledge is easy to record in a flexible format, and is readily available for analysis by subsequent missions. Previous attempts at using lessons learned recorded in documents has been inadequate due to the large time and effort required to thoroughly research them. Use of a tool which provides easy and flexible knowledge recording and searching engines is essential. Refer to the case based reasoning lessons learned tool developed by Code 520 and the Code 501 lessons learned work.

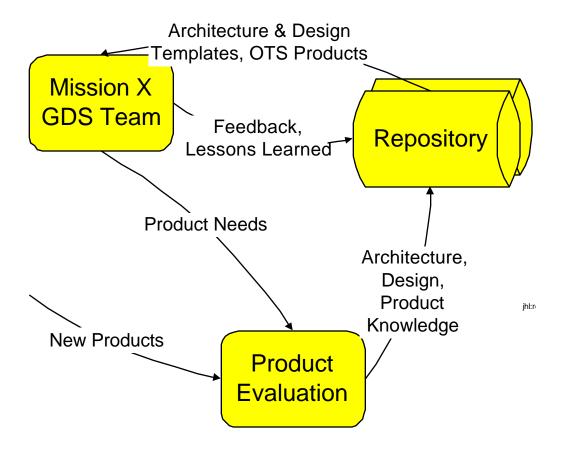


Figure 4-1. Repository Maintenance.

4.3 Building Blocks

Internally produced building blocks ideally result from a thorough domain analysis and object oriented development using the agent-domain-transaction techniques. These are produced and maintained by the mission support centers of expertise within the MO&DSD. These internally produced products may additionally contribute to research in engineering or production disciplines. These building blocks also include the first generation, but are increasingly populated with collections of class libraries from which mission tailored executable programs are built. This approach presents several advantages in that the mission tailoring can produce a very highly cohesive system. The disadvantage is the development and maintenance costs are probably higher due to the semi-custom nature. This approach is preferred for those functional areas for which no suitable OTS components are available, and for which technology can be advanced. It is expected that MO&DSD research and development efforts will lead to internally developed building blocks that are subsequently commercialized. Note that internally produced software also carries a support risk much like commercial products.

The list of available COTS products is expanding rapidly, and the current selection is adequate to assemble a tailored GDS for much of a typical mission as has been demonstrated by the Renaissance 90 day IMACCS prototype. Vendor offerings and trends must be monitored on a continuing basis in order to stay abreast of the latest products. Older products will eventually not be maintained by the vendor. Upgrades will be offered which may or may not be desirable for a

specific mission depending on the frequency of the upgrades and the mission duration. For short missions, upgrades and the associated costs may not be required.

One of the benefits of integrating COTS products is that the development costs have already been spent by the vendor and presumably amortized over multiple clients. Profits from current sales are likely to be reinvested into improvements of the products or expansion of the product line. Some vendors will be recycling GOTS legacy software under a commercial cover, but even this can be positive when the vendor assumes a significant portion of the product risk and distributes the ongoing maintenance and improvement costs across multiple clients. Vendors are also motivated to produce quality products by competition. Further, where there are several alternatives, the best can be selected for use.

Like other OTS system components, COTS products carry risks associated with producer (vendor) viability. For COTS products, this risk can be mitigated by escrow storage of the source code. The fallback position would be to incorporate the product into the MO&DSD software stores, or to locate a new vendor to assume responsibility for the product.

A wide selection of system components are also available from NASA, DoD, and other government projects (much like the MO&DSD first generation building blocks based on legacy systems). These building blocks are of greatest cost advantage when they are treated like COTS building blocks to minimize the maintenance costs. The programs require building and the source code requires configuration management, but these can be cost effective if maintenance changes are not made within the MO&DSD, but rather desired evolution is fed back to the originating organization much like feedback to a COTS vendor. Source code modifications can be made inhouse by MO&DSD when the maintenance costs are warranted by mission needs and generalizations. These products also have an increased integration risk and cost.

4.4 Building Block Qualification

The repository is intended to contain knowledge about all aspects of GDS production: templates of architectures and designs, building blocks, and known methods of integration and configuration. This knowledge is qualified by the system engineering team before placement in the repository. New products and technologies as well as knowledge from mission teams are evaluated as candidates for the repository. This qualification process is performed to quantify performance and capability. Upgrades are evaluated against needs for current missions. Return on investment for new COTS is traded against the cost of updates to infrastructure and standards.

Section 5. Configuration Management:

Configuration management in the Renaissance era is a combination of both centralized control through the qualified MO&DSD repository, and distributed control for each mission customer and mission support COEs based on the data model illustrated in figure 5-1.

As is established and customary, each mission customer will receive a configured and controlled mission library which contains the integrated GDS tailored for that mission's needs. Each mission library will include copies of all building blocks including licensed COTS and any GOTS or internally produced building blocks. Configuration control for each specific mission GDS is only as formal as is determined to be needed by the mission team leader.

MO&DSD mission support COEs which produce internal building blocks will each configure and control their respective products and may control copies of other GOTS products for MO&DSD use. The COTS and GOTS vendors maintain their own internal product configuration.

The MO&DSD repository may also contain copies of site-licensed COTS and qualified versions of MO&DSD produced building blocks and other GOTS. The Renaissance repository will be configured and controlled as a directorate resource. It will contain meta-data (e.g., product descriptions and integration techniques) and other data derived from market analysis and mission feedback.

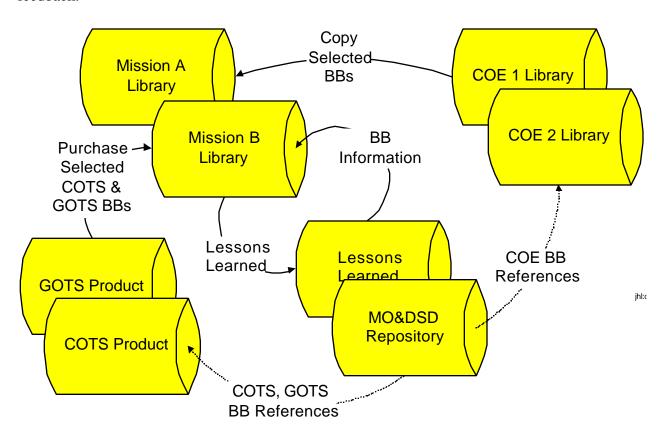


Figure 5-1. Renaissance Data Model

Section 6. Risk Analysis

6.1 Risk Management Process

Risk management has two facets:

- Risk assessment encompasses identifying the risks of not achieving various aspects of the mission goals, developing plans that reduce the probabilities of occurrence, and monitoring to detect the onset of the risks.
- Risk mitigation is the implementation and monitoring of plans with contingencies to control the effects of risks that may occur.

In the coming series of small, low cost missions, acceptable levels of risk must be weighed against the cost of mitigation. The traditional approach of risk avoidance produced a low failure rate, but has become much too costly. To manage risks, the risks are identified and translated into the common units of cost. The probability of occurrence is used to calculate the probable cost of the total of all risks over time. The cost of mitigation approaches are calculated and weighed against the probable loss due to the occurrence of risk.

6.2 Risk Mitigation by Prototyping

The overall rapid prototyping process not only greatly reduces the costs for requirements gathering and system validation, but also reduces risk. Prototyping allows developers to eliminate uncertainties early by determining that OTS products work as expected, and system integration and configuration is understandable and cost effective. It helps determine the platform size, data model, and communication topology, and to demonstrate that the system will perform to the end-user's expectations. Approaches to resolving specific problems are clearly identified, and alternatives are selected early to avoid cost and schedule impact.

In the early phases, prototyping helps to determine high-level acceptability of various candidate solutions and identify marketing hyperbole for any products not already qualified and in the MO&DSD repository. Prototyping results are demonstrated to get early and repeated feedback from the mission customer on the acceptability of the "look-and-feel," functionality, and performance of the system.

Early prototyping is also important for arriving at improved effort and schedule estimates, particularly when the integration process effort model is being calibrated and when new products are evaluated. The prototypes are modified to become the operational mission GDS.

Appendix A.

A.1 Process Guide Supplements

This *Process Guide* is by no means complete. It addresses the market for scientific, unmanned spacecraft missions which require ground support. It should be supplemented with studies in the following areas to form a comprehensive marketing strategy.

- Enumerate mission support centers of expertise in MO&DSD (e.g., orbit design, spacecraft health and safety monitoring, communications and networking technologies, software development methods).
- Identify supportive or secondary markets.
- Define metrics for both mission and system engineering processes.
- Construct an MO&DSD iInformation system process, infrastructure, policy and tools.
- Explore outsourcing and privatization options.

Abbreviations and Acronyms

ADT Agent-Domain-Transaction extensions to Object Oriented methods

API Application program interface

BB Building Block

COE Center of expertise

COTS Commercial off-the-shelf

DMR Detailed Mission Requirements document

DoD Department of Defense

GDS Ground data system (for spacecraft support)

GOTS Government off-the-shelf

GSFC Goddard Space Flight Center

IMACCS Integrated Monitoring, Analysis, and Control COTS System

I&T Integration and test

MOC Mission Operations Center

MOCD Mission Operations Concept Document

MO&DSD Mission Operations and Data Systems Directorate (Code 500)

MRR Mission Requirements Request document

NASA National Aeronautics and Space Administration

OTS Off-the-shelf (e.g., as in existing software products)

SIRD Support Instrumentation Requirements Document

SOC Science Operations Center

SORD Systems and Operations Requirements Document

SRD System Requirements Document

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